Wave-Sediment Interaction in Muddy Environments: Subbottom Field Experiment

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LONG-TERM GOALS

The proposed work investigates quantitatively the interaction between wave, currents and seabed sediments in shallow water over a bed characterized by heterogeneous, mud-dominated sediments. The long-term goal of is to develop an approach to characterize accurately the state of a muddy sea bed, based on minimal prior information about bed sediment, and remote observations of surface waves and currents.

OBJECTIVES

The objective of the project is to investigate the possibility to predict bottom sediment processes using field data collected during the MURI Wave-Mud experiment. The data will be used to validate the model and propose simplifications for operational implementations. These goals are aligned with all three major ONR research thrust areas: nearshore, estuarine and riverine processes; remote sensing of the coastal environment; and sediment transport.

APPROACH

Bottom tripods were deployed on the Atchafalaya inner shelf to carry out time-series examination of fluid, flow and suspended sediment conditions for 1-2 month periods. Tripod deployments were supplemented by ship-based coring at the sites and meteorological observation time-series instrumentation deployed on nearby oil and gas platforms.

WORK COMPLETED

Field experiment and data analysis: The “Sub-bottom Field Experiment” project provided information about the evolution of the bed under wave action. In support the data collection effort of the Traykovski/Trowbridge group, the project deployed instrumentation to capable of high-resolution measurements of full water column hydrodynamics and near-bed sediment dynamics. An example of an instrumented platform is shown in Figure 2.

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RESULTS

Field Experiments: Figure 3 shows and example of observations of waves and bed state response (this case: a frontal storm observed in March 2008). The event is associated with fairly energetic southward winds and currents which seem to be due to a superposition of low tide and the flushing of the coastal setup post-frontal storm passage. The sea-floor response can be inferred from the PC-ADP acoustic backscatter (Figure 3c), based on the location of maximum intensity. At P3, bed elevation changes by 10-15 cm, consistent with previous observations (Jaramillo et al., 2008; Sheremet et al., 2010), and suggesting a significant bed reworking and wave-sediment coupling.

IMPACT/APPLICATIONS

Much of the present and near-future Navy capability on predicting regional and nearshore processes assumes a sandy (non-cohesive) sedimentary environment. The present research enhances this capability by providing field data essential for model validations and by identifying processes and developing mechanisms which allow expansion into areas with significantly different characteristics.

One of the direct implications of the present research is the developing the foundation for the development of a coupled hydrodynamic-seafloor prediction model for muddy environments.

RELATED PROJECTS

The project represents a convergence of several directions of research (near-shore wave modeling, cohesive sediment transport, the development of operational forecasting tools for near-shore circulation and waves, increase use of remote sensed information, etc) and etc), and collaboration efforts circumscribed by the MURI-lead effort to understand wave-mud interaction.

The field experiment is coordinated in collaboration with other MURI related projects. The scope and approach of the present research builds on the strong, ongoing collaboration between U. Florida and U. Texas and U. Delaware, illustrated by a number of papers in print and in preparation. The field work was coordinated with with the MURI group of researchers, especially regarding observational data sharing (boundary layer and sediment characteristics, Traykovski, Kineke, Dalrymple), and other researchers that participated in the MURI-lead field experiment (Elgar, Raubenheimer, Allison). The work represents a natural continuation and expansion of the PIs ongoing research projects. The proposed work also builds on our previous collaborations on wave modeling with Kaihatu (Texas AM).

This research also benefits from, and enhances, parallel research (Sheremet) funded under NOPP to improve existing operational wave-forecasting systems (WaveWatch III, SWAN, etc) by developing and implementing numerical modules for wave-mud interaction and nonlinear waves physics.

The bottom boundary layer fluid mud modeling component of the proposed work also benefits from, and enhances parallel research (Hsu) funded by ONR to develop multidimensional, turbulence resolving model for fine sediment transport driven by waves and tidal currents.

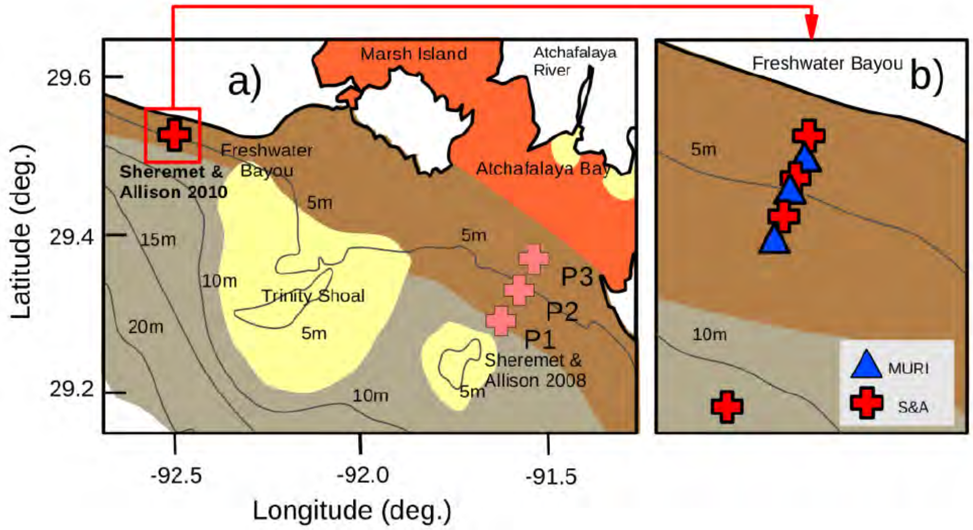

Figure 1: a) Plan view of the Atchafalaya shelf showing the location of the experiments conducted in 2008 (light red crosses, platforms P1-3) and 2010 (MURI) red cross. b) Magnified area of the 2010 MURI experiment with the locations of the three MURI platforms (blue triangles) and Sheremet & Allison array (red crosses). An ADCP and a pressure sensor were deployed farther offshore (approx. 18-m depth) to provide boundary conditions for wave propagation.

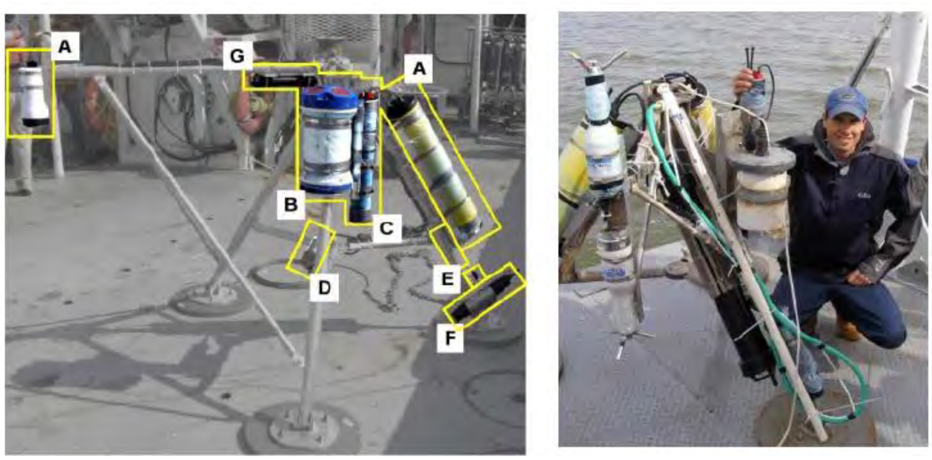

Figure 2: Left: An instrumented platform ready for deployment. Deployed instrumentation included downward-looking PC-ADP (A), upward-looking ADCP (B), an ABS (C), a CT probe (D), turbidity sensors – one OBS-5 (F), and two OBS-3 (E, one is partially visible behind the OBS-5). An acoustic pinger (G) is used to locate the deployed tripod. Right: the pore-pressure array ready to be deployed (Spring 2010) and his designer, Uriah Gravois (U. Florida graduate student). The black cylinder contains the electronics (Onset Computer Corporation Tattletale 8 Data logger, Persistor Memory Expansion (Paroscientific Pressure Sensor included in the housing). The long white cylinder is the probe, containing 4 sets of pore-pressure sensors and thermistors. Two Sontek Hydra ADVs and their battery canister (large white cylinder) can also be seen mounted on the tripod.

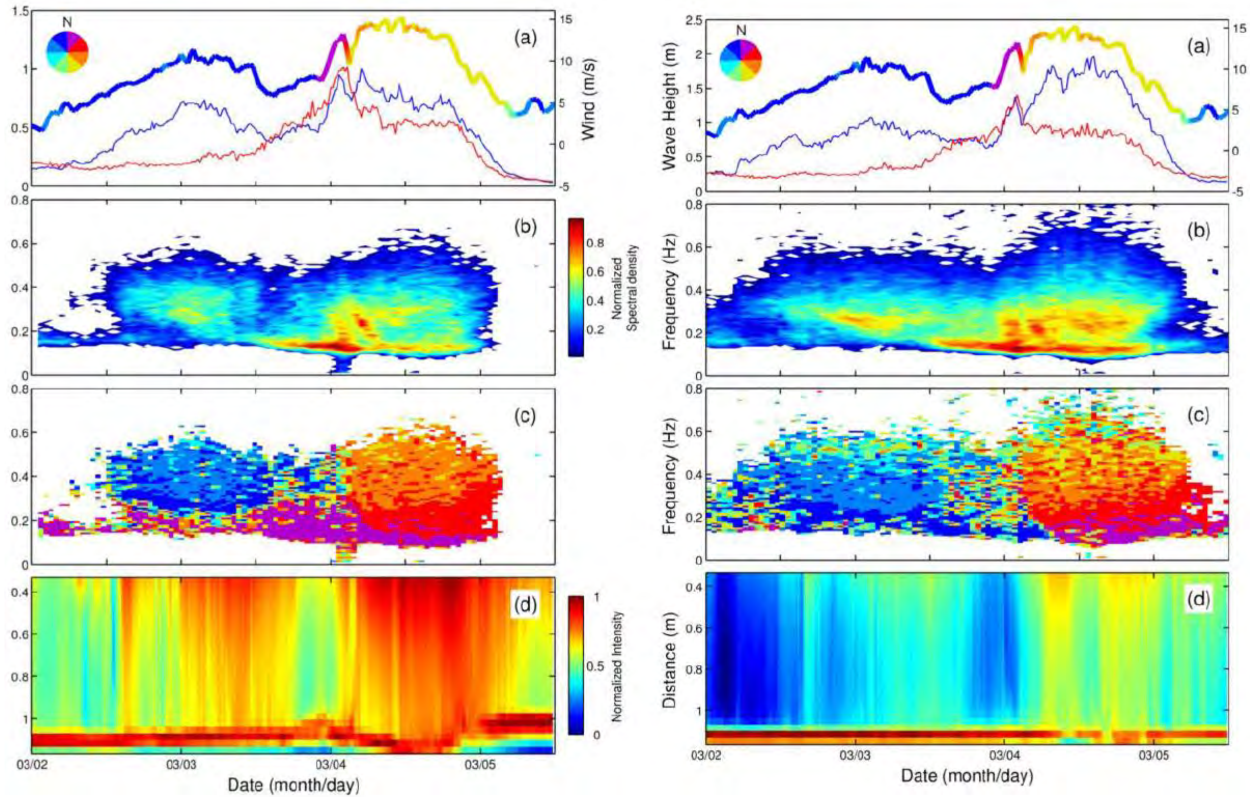

Figure 3: Observations of waves and suspended sediment concentration (SSC) at two platforms (P1 and P3, see Figure 1). Left: P1 (29 deg 11.815, 91 deg 36.731 W), 7-m depth. Right: P3 (29 deg 15.574, 91 deg 34.267W), 4-m depth. (a) Significant wave height of sea (blue, f>0.2 Hz) and swell (red, f≤0.2 Hz) bands. Multi-color curve shows the wind speed and direction. (b) Normalized spectral density of the sea surface elevation. (c) Peak wave propagation direction for each frequency band in the power spectrum (for both winds and waves, the directions indicate where the flow is toward, i.e., N means toward North). The wave directions are shown only for frequencies with spectral density above some "significance threshold" (arbitrary). (d) Normalized acoustic backscatter records of the downward-looking PC-ADP.

REFERENCES

Agnon, Y. and A. Sheremet (1997). Stochastic nonlinear shoaling of directional spectra, J. Fluid Mech. 345, 79-99.

Allison, M.A., G.C. Kineke, E.S. Gordon, and M.A. Goni (2000). Development and reworking of a seasonal flood deposit on the inner continental shelf off the Atchafalaya River, Continental Shelf Res. 20, 2267-2294.

Chan I.-C., and P.L.-F. Liu (2009). Responses of Bingham-plastic muddy seabed to a surface solitary wave, J. Fluid Mech. 618, 155-180.

Chen, Y., R.T. Guza, and S. Elgar (1997). Modeling spectra of breaking surface waves in shallow water”, *J. Geophys. Res*. *102/C11*,25,035-25,046.

Chou, H.-T. (1989). Rheological Response of Cohesive Sediments to Water Waves, Berkeley, California: University of California at Berkeley, Doctoral thesis, 149p.

Chou, H.-T., M.A. Foda, and J.R. Hunt (1993). Rheological response of cohesive sediments to oscillatory forcing”, In: Nearshore and Estuarine Cohesive Sediment transport, Coastal Estuarine Sci., 42, A.J. Mehta ed., 126-148, AGU, Washington DC.

Dalrymple, R.A. and P.L.-F Liu (1978). Waves over soft muds: a two-layer fluid model, J. Phys. Oceanogr. 8, 1121-1131.

De Witt, P.J. (1995). Liquefaction of cohesive sediments caused by waves, Delft Studies in Integrated Water Management 6, Delft University Press.

Elgar, S., and B. Raubenheimer (2008). Wave dissipation by muddy seafloors, Geophys. Res. Lett. 35/7, L07611.

Foda, A.M., J.R. Hunt, and H.-T. Chou (1993). A nonlinear model for the fluidization of marine mud by waves, J. Geophys. Res. 98, 7039-7047.

Foda M.A. and S.Y., Tzang (1994). Resonant fluidization of silty soil by water waves, J. Geophys. Res. 99(C10*)*, 20463-20475.

Freilich M.H. and R.T. Guza (1984). Nonlinear effects on shoaling surface gravity-waves, Phil. Trans. Royal Soc. London Series A 311, 1-41.

Gade, H.G. (1957). Effects of a non-rigid impermeable bottom on plane surface waves in shallow water, Ph. D. Thesis, Texas A&M University, 35 pp.

Hill, D.F. and M.A. Foda (1999). Effects of viscosity on the nonlinear resonance of internal waves, J. Geophys. Res. 104, 10951-10957.

Holland K.T., S.B. Vinzon, L.J. Calliari (2009). A field study of coastal dynamics on a muddy coast offshore of Cassino beach, Brazil, Cont. Shelf Res. 29, 503–514.

Hsu, T-.J., C.E. Ozdemir, and P.A. Traykovski (2009). High-resolution numerical modeling of wave- supported gravity-driven mudflows, J. Geophys. Res., 114, C05014, doi: 10.1029/2008JC005006.

Jamali, M., B. Seymour, and G. Lawrence (2003), Asymptotic analysis of a surface-interfacial wave interaction, Phys. Fluids 15, 47-55.

Jaramillo, S., A. Sheremet, M. Allison, and K.T. Holland (2009). Wave-mud interactions over the muddy Atchafalaya subaqueous clinoform, Louisiana, United States: Wave-supported sediment transport, J. Geophys. Res., 114, C04002, doi:10.1029/2008JC004821.

Jiang F. and A.J. Mehta (1995). Mudbanks of the Southwest Coast of India IV: Mud viscoelastic properties, J. Coastal Res. 11, 918-926.

Kaihatu J.M., A. Sheremet, and K.T. Holland (2007). A model for the propagation of nonlinear surface waves over viscous muds, Coastal Engineering 54, 752-764.

Le Hir, P., P. Bassoulet, and H. Jestin (2001), Application of the continuous modeling concept to simulate high-concentration suspended sediment in a macro-tidal estuary, in Coastal and Estuarine Fine Sediment Processes, edited by W. H. McAnally and A. J. Mehta, Elsevier, Amsterdam.

Mei, C.C. and P.L-F. Liu (1987). A Bingham-plastic model for a muddy seabed under long waves", *J. Geophys. Res. 92*, 14,581-14,594.

Ng, C.-O. (2000). Water waves over a muddy bed: a two-layer Stokes's boundary layer model, Coastal Engineering, 40, 221-242, 2000.

Robillard, D., (2008). A Laboratory Investigation Of Mud Seabed Thickness Contributing To Wave Attenuation, PhD. Dissertation, Online: http://purl.fcla.edu/fcla/etd/UFE0024823, University of Florida, Gainesville, FL, 2008.

Rogers, E., and K.T. Holland (2009). A study of dissipation of wind-waves by viscous mud at Cassino Beach, Brazil: prediction and inversion, Cont. Shelf Res. 29, 676-690, 2009.

Safak, I, A. Sheremet, M.A. Allison, and T.-J. Hsu (2010). Bottom turbulence on the muddy Atchafalaya Shelf, Louisiana, USA, J. Geophys. Res., 115, C12019, doi:10.1029/2010JC006157.

Sheremet, A. and G.W. Stone (2003). Observations of nearshore wave dissipation over muddy sea beds, J. Geophys. Res. 108, DOI 10.1029/2003JC001885.

Sheremet A., A.J. Mehta, B. Liu, and G.W. Stone (2005). Wave-sediment interaction on a muddy inner shelf during Hurricane Claudette, Est. Coastal Shelf Sci. 63, 225-233.

Sheremet, A., S. Jaramillo, S.-F. Su, M.A. Allison, and K.T. Holland (2011). Wave-mud interaction over the muddy Atchafalaya subaqueous clinoform, Louisiana, United States: Wave processes, J. Geophys. Res., 116, C06005, doi:10.1029/2010JC006644.

Torres-Freyermuth, A., and T.-J. Hsu (2010). On the dynamics of wave-mud interaction: a numerical study, J. Geophys. Res., 115, C07014, doi:10.1029/2009JC005552.

Yamamoto, T. and S. Takahashi (1985). Wave damping by soil motion", J. Waterway, Port, Coastal, and Ocean Eng. 3, 62-77.

PUBLICATIONS

Sheremet, A., S. Jaramillo, S.-F. Su, M.A. Allison, and K.T. Holland (2011). Wave-mud interaction over the muddy Atchafalaya subaqueous clinoform, Louisiana, United States: Wave processes, J. Geophys. Res., 116, C06005, doi:10.1029/2010JC006644 [published, refereed].

Safak, I, A. Sheremet, M.A. Allison, and T.-J. Hsu (2010). Bottom turbulence on the muddy Atchafalaya Shelf, Louisiana, USA, J. Geophys. Res., 115, C12019, doi:10.1029/2010JC006157 [published, refereed].

Jaramillo, S., A. Sheremet, M. Allison, and K.T. Holland (2009). Wave-mud interactions over the muddy Atchafalaya subaqueous clinoform, Louisiana, United States: Wave-supported sediment transport, J. Geophys. Res., 114, C04002, doi:10.1029/2008JC004821 [published, refereed].

CONFERENCE PRESENTATIONS

Kaihatu, J.M. , N. Tahvildari, C. Sahin, and A. Sheremet, Verification of Wave-Mud Interaction Models with Field Data, 12th International Workshop on Wave Forecasting and Hindcasting and 3rd Coastal Hazards Symposium, Hawaii 2011.

Sahin, C., I. Safak, A. Sheremet, and J. M. Kaihatu, Coupled wave-bed dynamics, Atchafalaya shelf, Louisiana, 12th International Workshop on Wave Forecasting and Hindcasting and 3rd Coastal Hazards Symposium, Hawaii 2011.

Sahin, C., I. Safak, A. Sheremet, M.A. Allison, Bed-sediment response to energetic waves, Atchafalaya inner shelf, Louisiana. Coastal Sediments 2011, Miami, FL.

Safak, I., C. Sahin, A. Sheremet, M.A. Allison, Observations and modeling of cohesive seafloor response to energetic surface waves on the Louisiana Shelf. CSDMS 2010: Modeling for Environmental Change, San Antonio, TX.

Sahin, C., I. Safak, A. Sheremet, M.A. Allison, Bed-sediment response to energetic waves, Atchafalaya inner shelf, Louisiana. AGU Fall Meeting.

Sheremet, A., M.A. Allison, I. Safak, S.-F. Su, Wave-sediment interaction on the Atchafalaya Shelf, Louisiana, USA, AGU Ocean Science Spring Meeting, Oregon, Portland 2010.

Sahin, C., I. Safak, A. Sheremet, and M.A. Allison, A method for estimating concentration profiles for suspended cohesive sediment based on profiles of acoustic backscatter, AGU Ocean Science Spring Meeting, Oregon, Portland, 2010.

Safak, I., A. Sheremet, S. Elgar, B. Raubenheimer, Nonlinear wave propagation across a muddy seafloor, AGU Ocean Science Spring Meeting, Oregon, Portland, 2010.

Safak, I., A. Sheremet, S. Elgar, and B. Raubenheimer, Nonlinear wave propagation on a muddy beach, West Louisiana, USA, International Conf. On Coastal Eng., 2010.

Allison, M.A., Sheremet, A., Safak, I., and Duncan, D.D., Floc behavior in high turbidity coastal settings as recorded by LISST: the Atchafalaya delta inner shelf, Louisiana. AGU Ocean Sciences Meeting, Portland, Oregon, February, 2010.